US CMS Technical Description and Rescope

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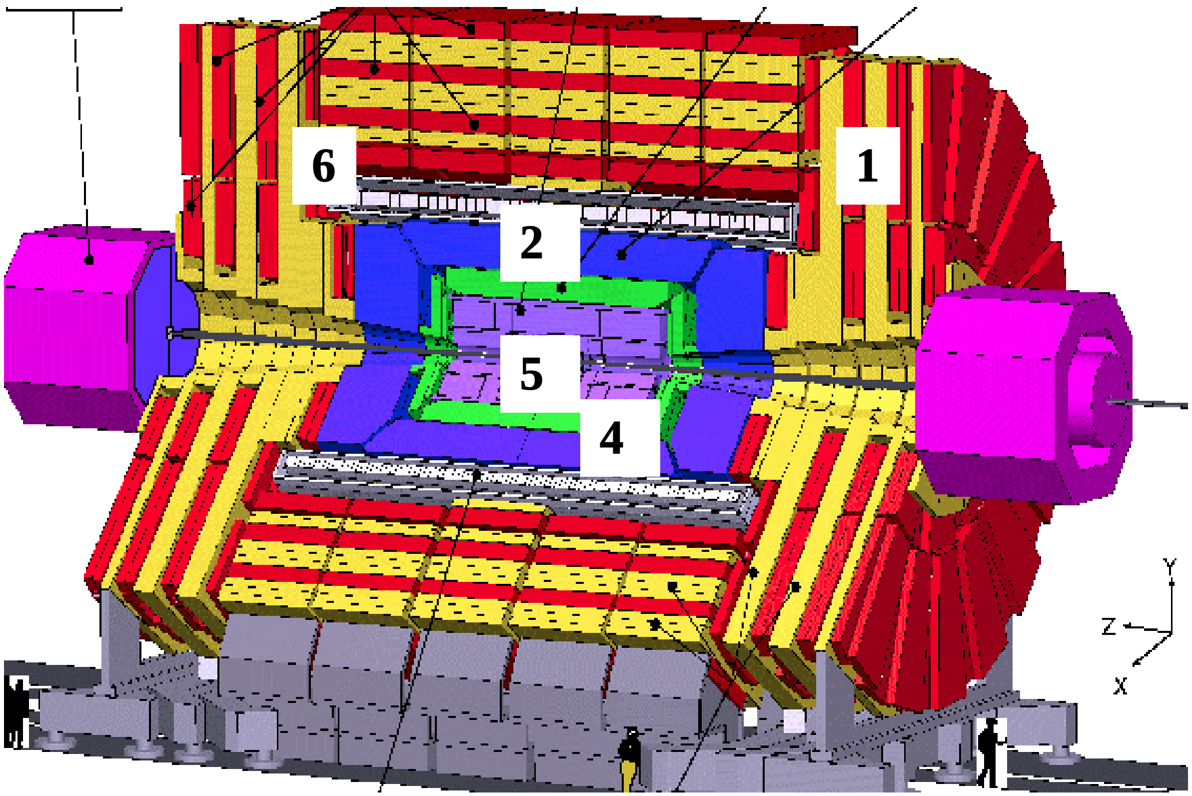
Outline

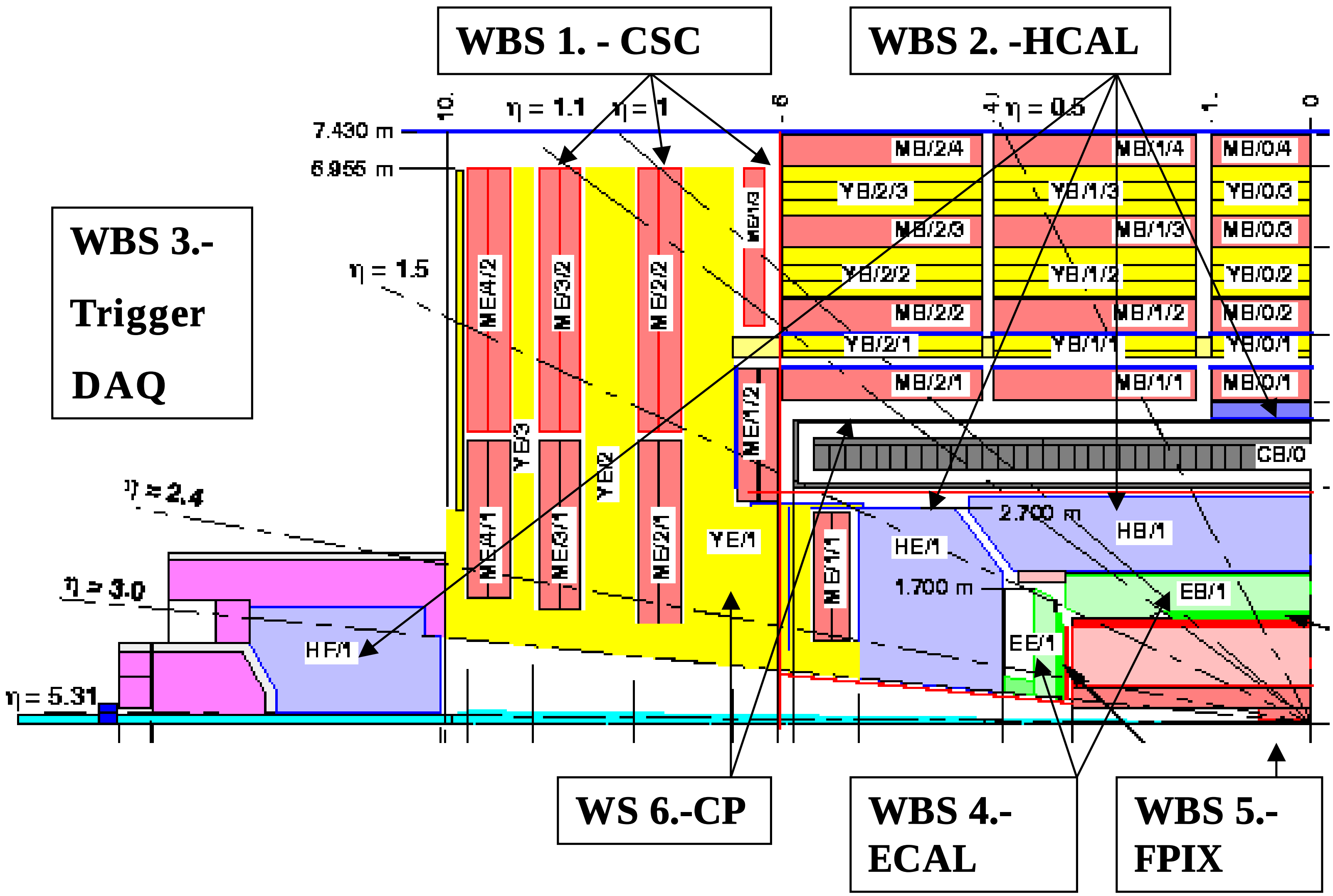
- US CMS Description
- US CMS Responsibilities
- Recent Technical Progress
- Rescoping the US CMS Contribution
- Committee Concerns and Actions Taken
- Summary and Conclusions

US CMS Description



1. Endcap Muon Cathode Strip Chambers
2. Hadron Calorimeter -full HB, HOB, HE and HF transducers and readout.
3. Endcap muon and calorimeter trigger. DAQ filter
4. Electromagnetic Calorimeter - barrel transducers, front end electronics, and laser monitor
5. Forward pixels
6. Common Projects - endcap yoke and barrel cryostat
7. Project office

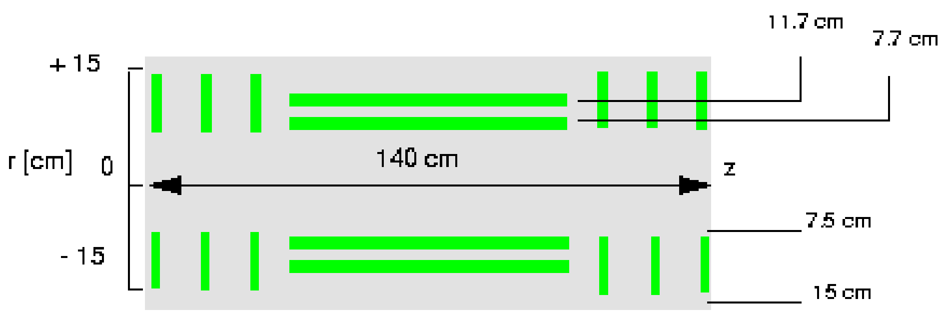
US CMS WBS


WBS 1. - CSC
WBS 2. -HCAL
WBS 3.- Trigger DAQ
WS 6.-CP
WBS 4.- ECAL
WBS 5.- FPIX
7.430 m
6.955 m
η = 1.1
η = 1
η = 0.5
η = 1.5
η = 2.4
η = 3.0
η = 5.31
MB/2/4
MB/1/4
MB/0/4
YB/2/3
YB/1/3
YB/0/3
MB/2/3
MB/1/3
MB/0/3
YB/2/2
YB/1/2
YB/0/2
MB/2/2
MB/1/2
MB/0/2
YB/2/1
YB/1/1
YB/0/1
MB/2/1
MB/1/1
MB/0/1
CB/0
ME/4/2
ME/3/2
ME/2/2
ME/1/3
ME/1/2
ME/4/1
ME/3/1
ME/2/1
ME/1/1
YE/3
YE/2
YE/1
HE/1
HB/1
EB/1
EE/1
HF/1
2.700 m
1.700 m

CMS Subsystems - FPIX

- The tracking system measures trajectories in a magnetic field, thus determining position and momentum of the produced particles. There are 3 components of tracking; silicon pixels, silicon strips, and microstrip gas chambers (MSGC). **US CMS is entirely responsible for the forward pixels (FPIX). There are now only 2 layers of FPIX.**

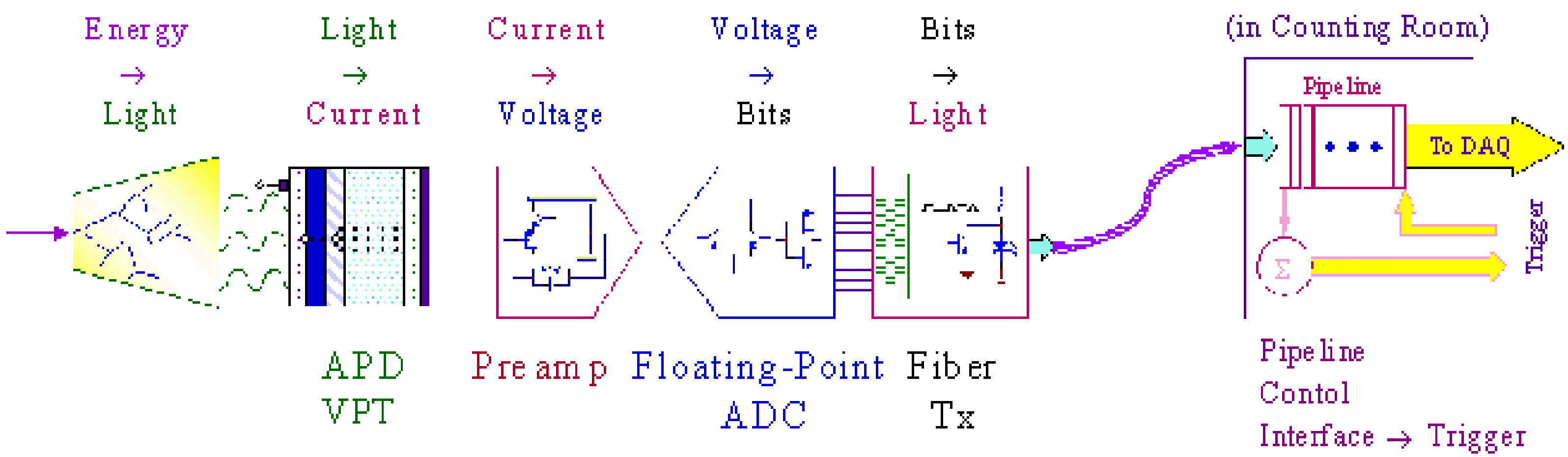
Detector Layout



An issue for the FPIX is to get good 3-D impact point resolution. This is achieved by "turbining" the pixels to get E x B charge sharing.

CMS Subsystems - ECAL

- The electromagnetic calorimeter (ECAL) measures the energy and position of the photons and electrons, which strike it. The ECAL system is made of transparent crystals of $PbWO_4$ read out by avalanche photodiodes (APD). US CMS is responsible for part of the barrel transducers (APD), digital conversion (FPU), the bit serializer, and part of the laser monitoring system. These responsibilities follow from the SDC and L3 experience of the US CMS ECAL groups.

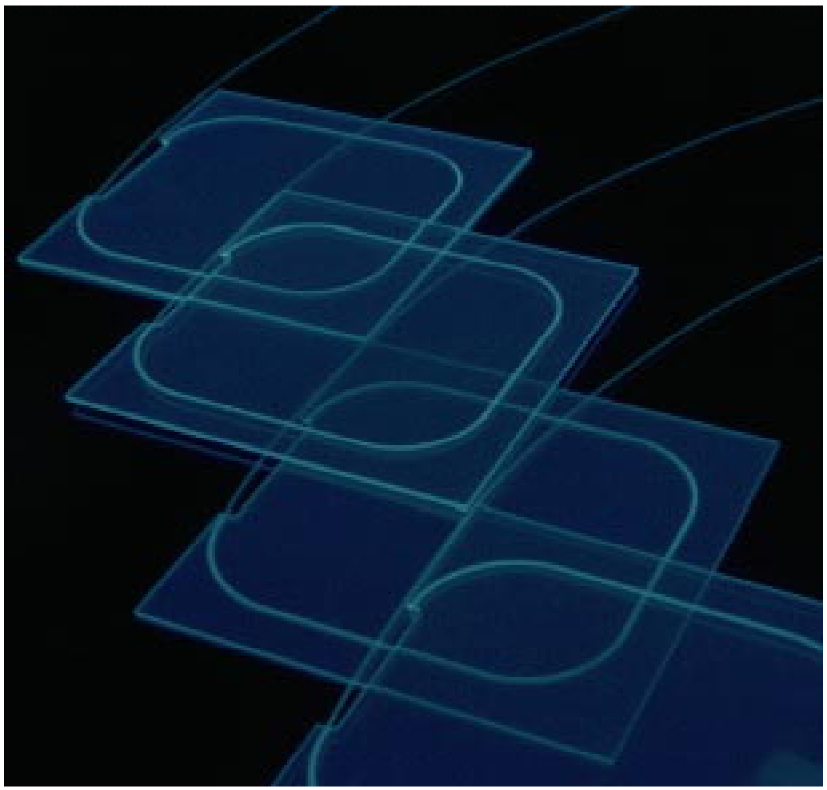


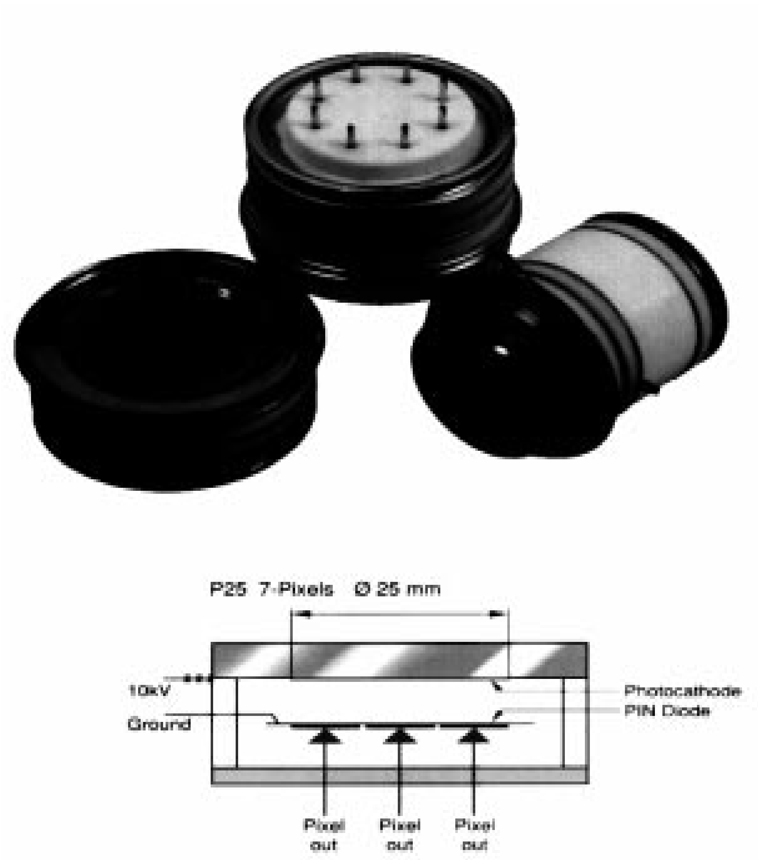
CMS Subsystems - HCAL

- **The hadron calorimeter (HCAL) measures the energy and position of all strongly interacting particles, which impinge upon it. It is built of scintillator tiles and wavelength shifter (WLS) fibers read out by hybrid photodiodes (HPD) in the barrel and endcap (HB and HE) and quartz fibers read out by photomultipliers (PMT) in the forward region (HF). US CMS is responsible for all the inner barrel and the transducers and readout electronics of all of HCAL.**

CMS Subsystems - HCAL

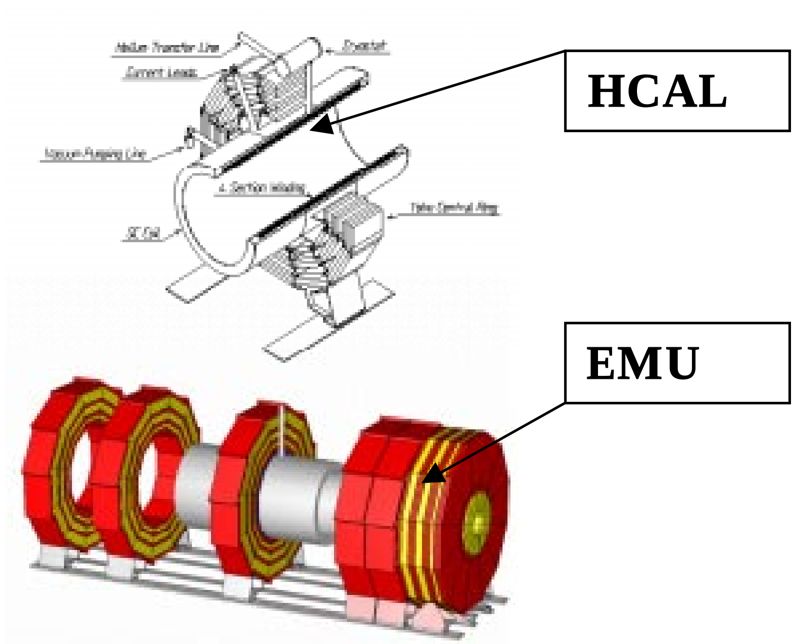
• The transducers are hybrid photodetectors which contain a photocathode and a PIN diode. These are new devices. The tile/WLS are from CDF and the ADC + pipeline are the QIE from KTeV.





CMS Subsystems - Magnet

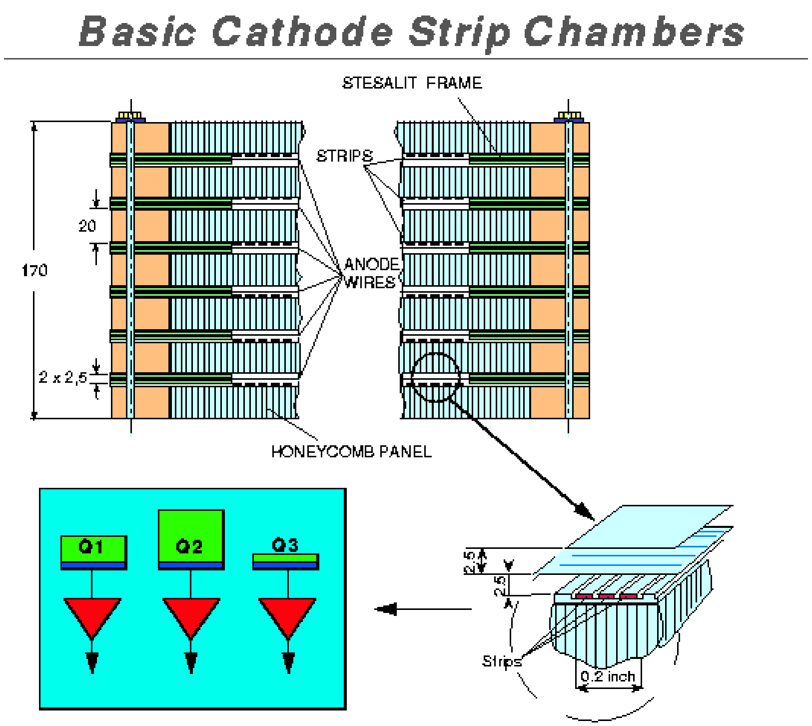
- **The magnet is a 4T electromagnet with a superconducting cryogenically cooled coil enclosed in a vacuum tank whose magnetic flux is returned by barrel and endcap steel (YB and YE). As part of the Common Projects of CMS, US CMS is responsible for the design and procurement of the entire endcap steel yoke, YE, and partial procurement of the magnet coil vacuum tank/cryostat**



This choice of CP follows from the US CMS efforts on HCAL and EMU CSC. At present, the barrel yoke/vac tank and the endcap yoke proposals are complete and on or under budget.

CMS Subsystems - Muons

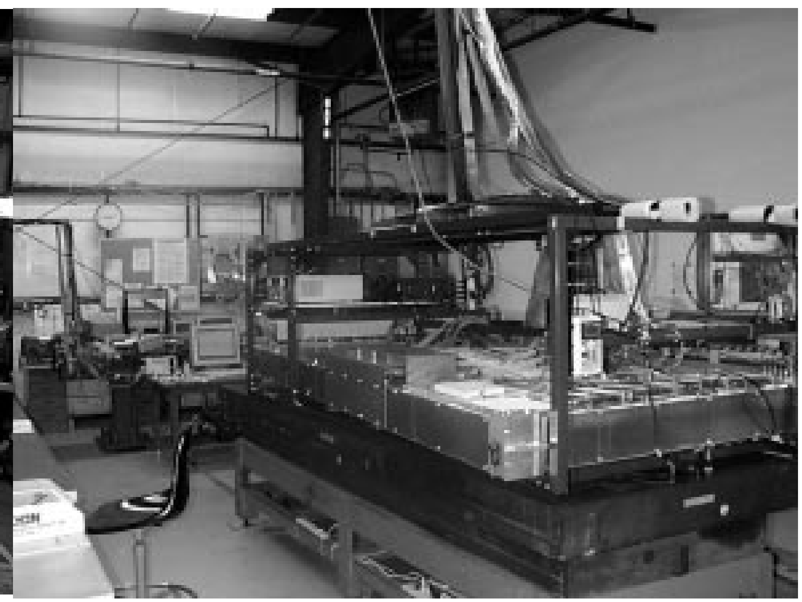
- **The muon system remeasures the momentum and position of the muons which survive the passage through all the other CMS detectors. The detectors are drift tubes in the barrel (MB) and cathode strip chambers (CSC) in the endcap (ME). Resistive plate chambers (RPC) are also used as a second, redundant, trigger system. US CMS is entirely responsible for the endcap CSC.**



The number of wires represents an order of magnitude increase over previous chamber work. Of necessity, tooling, engineering and automation are extensively applied. The electronics must have good S/N if the ultimate momentum resolution is to be achieved.

CMS Subsystems - EMU

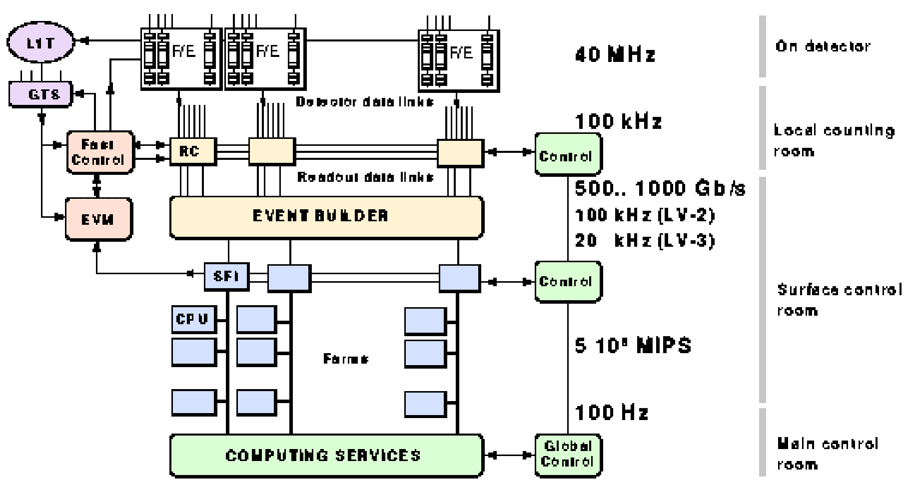
- The "P2 Preproduction Prototype" is a proof of principle for the new semi-automated assembly techniques.



CMS Subsystems - TRIDAS

- The CMS detector operates at 10^9 interactions/sec. The function of the trigger system is to first reduce the rate to <100 kHz of interesting events (L1) and then to 100 Hz of events to be saved for later examination (L2). The function of the data acquisition system (DAQ) is to assemble the full event from the subsystem data and record it on some permanent medium. **US CMS is responsible for the L1 muon and calorimeter triggers, the output DAQ filter units, and the DAQ event manager.**

Trigger and data acquisition layout



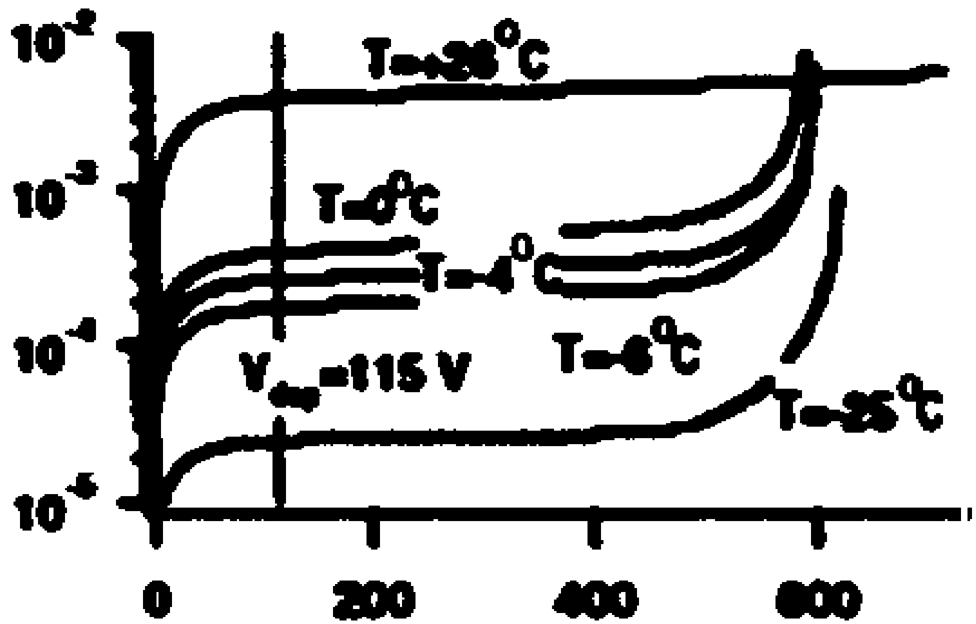
The US CMS jobs follow from our EMU and HCAL responsibilities and from our expertise in high rate DAQ (e.g. CDF).

US CMS Technical Progress

- The design status of US CMS is formalized in the TDR's which are now completed and accepted by the LHCC.
- US CMS has moved out of an R&D phase and into preproduction in FY98.
- In FY98 the PPP for HCAL and EMU will be built and CSC and tile/fiber "factories" will be set up for production in FY99.

Technical Progress - FPIX

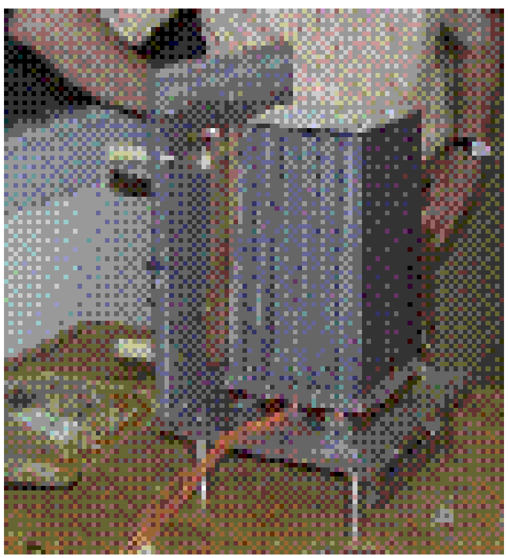
- The design is defined - TDR. Equal spatial resolution in 3-D is achieved.
- R&D on sensors - n, γ irradiation, p stops and guard rings ==> biases up to 500 V. This means the sensors will survive several years.



- The thermal and mechanical design is well advanced.
- Evaluation of the ROC from PSI is underway.

Technical Progress - ECAL

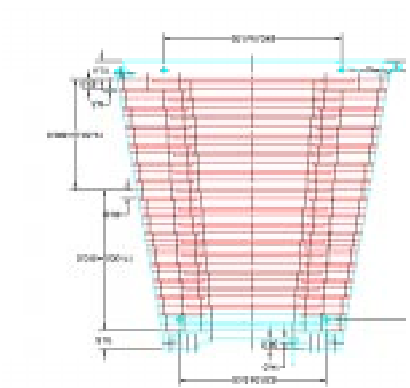
- APD evaluation - vendor choice March
- CHFET Bit Serializer - Honeywell submission
- FPU - completed in DMILL



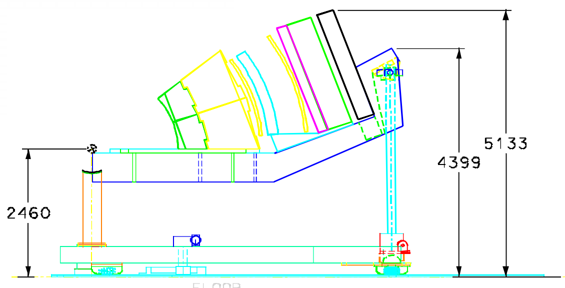
'98 test beam - full "light to light" test.

Full radiation hard front end chain and crystal in 1998.

Technical Progress - HCAL

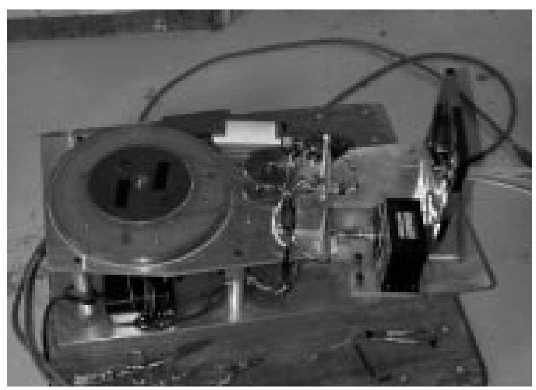


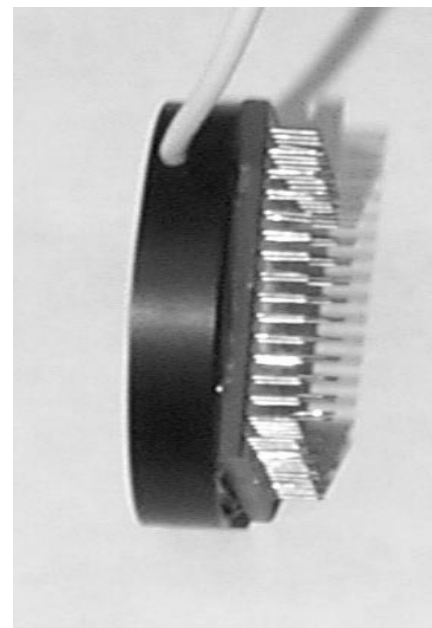
The first preproduction prototype is being built. The entire set of barrel wedges has been designed, bid, and the contract has been awarded. The optics CAM is complete.



Test beam '98 will use PPP1 and a motion table with full "factory" optics, HPD and preamp.

Technical Progress - HCAL





Technical Progress - TRIDAS

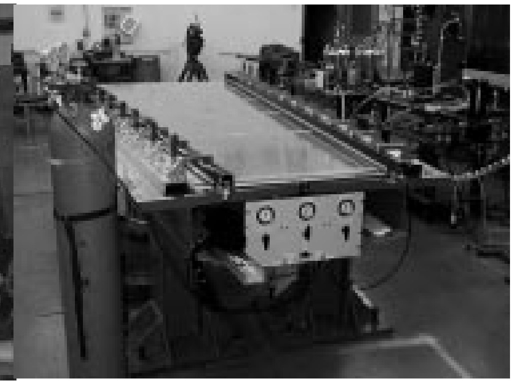
- L1CAL: Adder ASIC tested. Receiver card and backplane in fabrication.
- L1MU: Comparater ASIC design complete. Cathode LCT built. To be used in test beam '98.
- ATM based Event Builder prototype used in CDF LIII trigger for Tevatron Run II.
- L2 trigger algorithm studies underway.

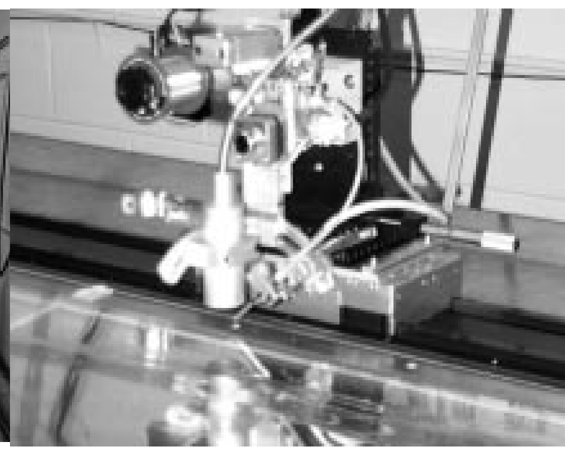
Technical Progress - EMU

- Factory tooling well advanced - e.g. automated wire soldering.
- Prototype P2 is full scale and built using “factory” tooling.
- ASICS for preamp/shaper, SCA, Comparator and LCT are in submission.
- Test beam ‘98 will use P2 with complete front ends and L1mu trigger. Tests in GIF will establish background toleration.

Technical Progress - EMU



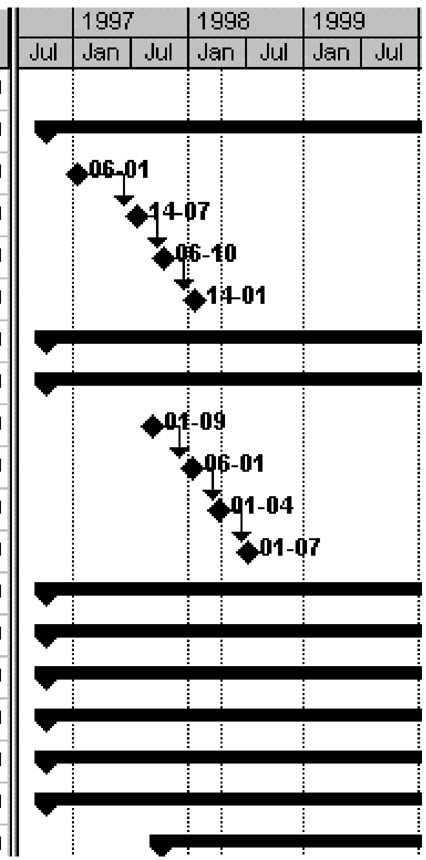





Technical Progress - CP

US CMS is responsible for design and procurement of the entire endcap steel (Wisconsin) and partial procurement of the barrel vacuum tank (Fermilab).

WBS	Task Name	Total Cost
1.1	US CMS End of Project	$0.00
6.1	**Pack A, Barrel Yoke and Vac Tank (23.3)**	**$8,103,600.00**
6.1.1	market survey complete (RFI)	$0.00
6.1.2	call for tenders (RFQ)	$0.00
6.1.3	open bids	$0.00
6.1.4	award contract	$0.00
6.1.5	**package payments**	**$8,103,600.00**
6.2	**Pack B, Endcap Yoke (18.0)**	**$13,585,000.00**
6.2.1	market survey complete (RFI)	$0.00
6.2.2	call for tenders (RFQ)	$0.00
6.2.3	open bids	$0.00
6.2.4	award contract	$0.00
6.2.5	**package payments**	**$13,585,000.00**
6.3	**Pack C, Superconductor (16.9)**	**$0.00**
6.4	**Pack D, Coil Winding (15.3)**	**$0.00**
6.5	**Pack E, CERN- power, He refrig, etc.(9.3)**	**$0.00**
6.6	**Pack F, In kind (1.8)**	**$0.00**
6.7	**Pack G , Common Funds(37.3)**	**$0.00**
6.8	**Common Project Software(3.6)**	**$560,000.00**

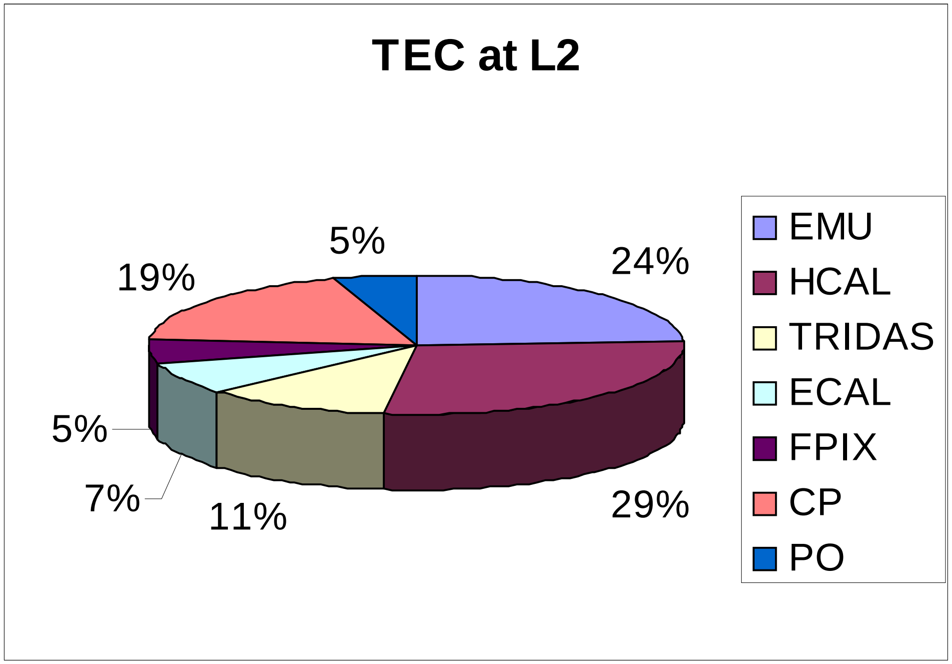


Technical Progress - CP

- The bid for the cryostat and barrel steel yoke came in within 10% of the CMS cost estimate. (package A)
- The RFI from CERN was responded to by at least one company within a few % of the cost estimate. The RFQ was opened in April. (package B - D. Loveless)
- The Saclay EDIA contract is let.
- The total committed is ~ 1/2 of the 121 MCHF of the Common Projects. Thus the 25% contingency on CP is ~ 50% of the cost to complete.

Engineering in the PO

- We mirror the CMS federal structure - connect to CMS at L2.
- Integration resides in the CMS PO - Integration Working Group
- We have hired 3 project engineers at L2 for EMU (N.C.), HCAL (M.R.), and CP(F.F.) and an E.E. for HCAL (S.L.)
- We will use the FNAL engineering pool for design reviews - e.g. PMG consultants for bottoms up cost/technical reviews.



The EMU plus HCAL plus CP cost estimates are 72% of the total TEC.

Rescoping

- June-October: L2 subsystems developed a resource loaded cost and schedule. Bottoms up new base cost estimates at L2.
- October-December: PMG review of L2 cost/schedule. Contingency assessment by L1 managers (DG+ET).
- December: US CMS proposed descope to CMS (DR+ET+DG/MDN).
- January: Meeting of US CMS Executive Committee with DG+ET to communicate the descope scenario to the collaboration for comment.
- January-February: Steering Committee I - present revised US CMS scope. Visit by MDN + JV to Fermilab. Steering Committee II - alternatives proposed by CMS and iterations. Management Board I - present the SC solution. By working together we achieve a better detector. CERN has the flexibility to reduce DAQ bandwidth.
- March: Present the US scope proposal to the full collaboration at CMS week. Add wording to the CERN MOU specific to US CMS.
- April-May: Prepare for baseline with agreed upon scope.

Contingency

The TD and CPM now believe that US CMS now has a contingency level consistent with recent HEP experience.

The contingency for the project is now 43%, 49% for the detector subsystems. The base cost has been reduced to maintain a fixed total cost.

Rescoping and Physics

- The goals of the rescope reflect our determination to maximize the Physics capability of CMS.
- The magnet is unchanged - keep the full magnetic volume.
- The full angular coverage is preserved.
- The detector systems have reduced redundancy and therefore reduced “headroom”.
- The scope reduction is designed to be recoverable.
- CMS will work together and speak with a single voice.

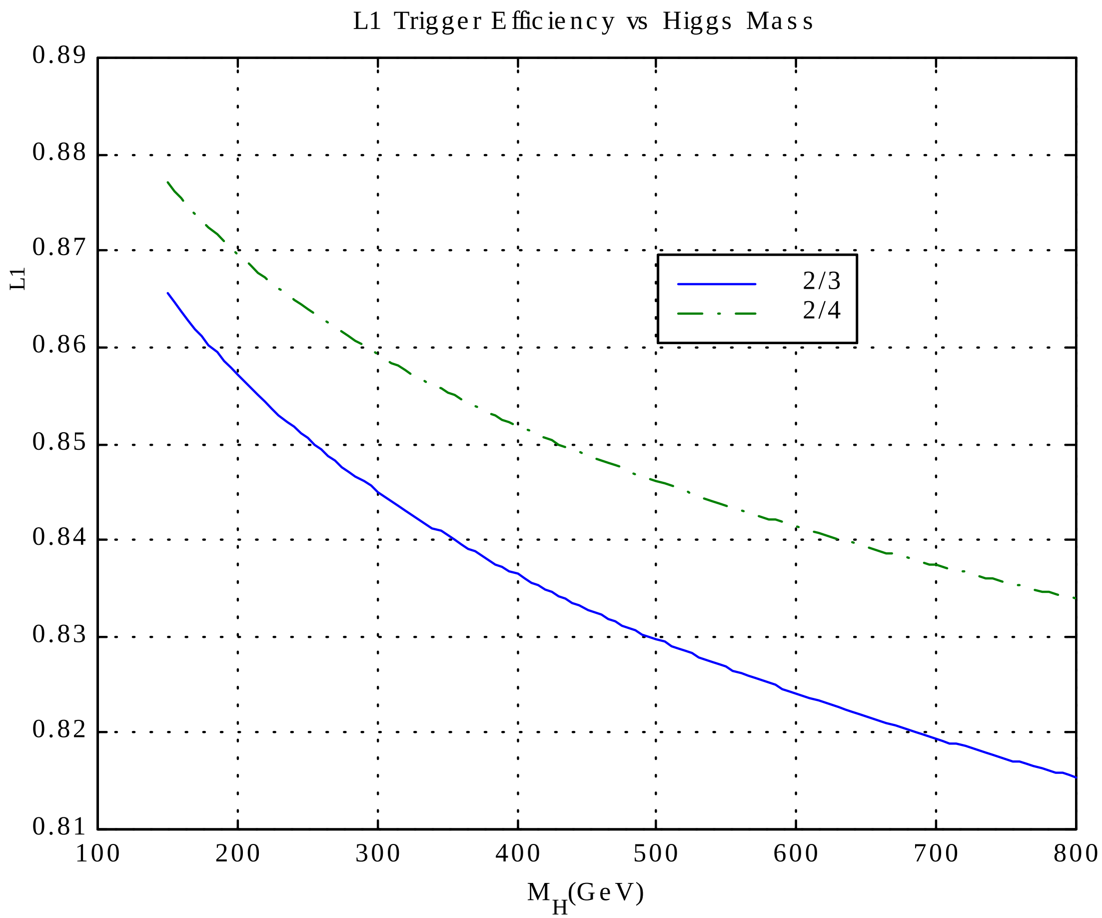
Rescoping and Physics

- WBS 1. - EMU: Remove MF4 and reduce alignment redundancy. Maintains the full angular range and most of the momentum resolution. The redundancy is reduced, leading to reduced trigger efficiency due to δ and γ rays. The loss for H --> ZZ --> 4l is small, assuming that triggering can be maintained at low Pt threshold. The “headroom” available in triggering and reconstruction is reduced but the test beam resolution of 0.7 mm argues for optimism.

L1 Triggers in 3 and 4 CSC Stations

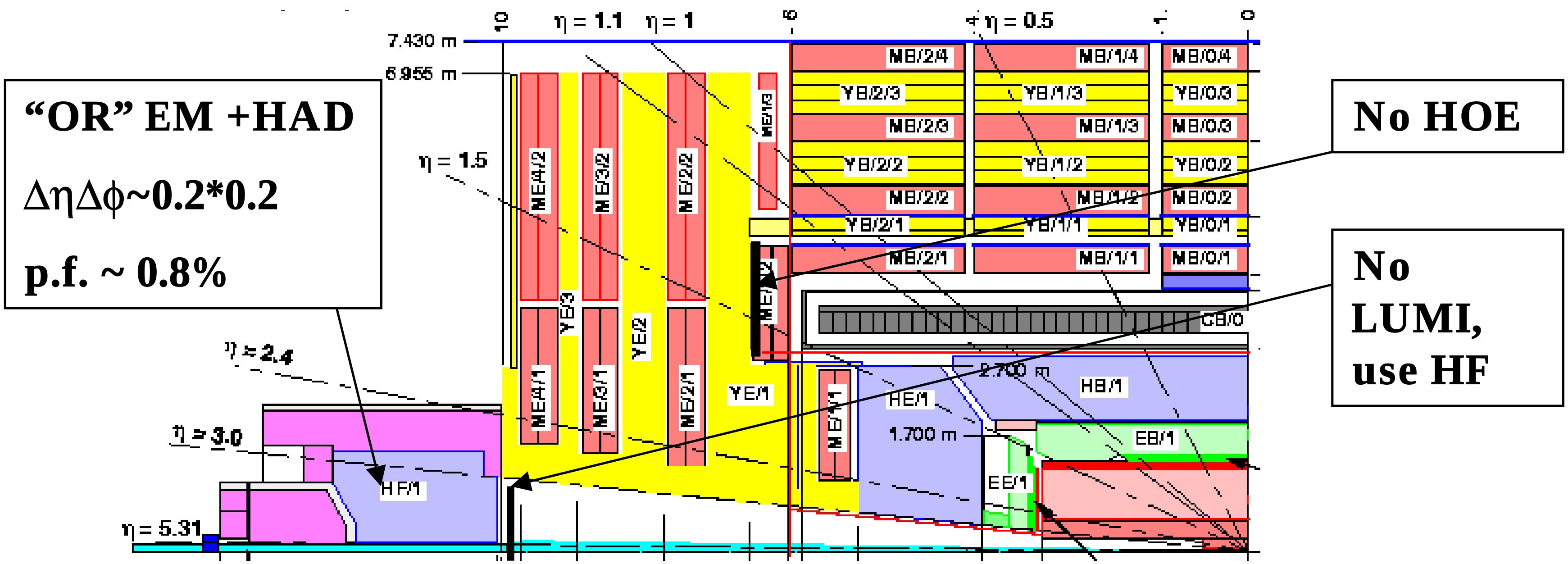
At |η| = 2 there are L1 trigger losses due to γ and δ accompanying the μ. If sufficient redundancy exists, the L1 trigger efficiency is not reduced strongly in going from 4 --> 3 stations.

ε_{L1}



Rescoping and Physics

- WBS 2. - HCAL: Remove HOE and LUMI. Reduce HF active % and transverse segmentation. Accept HB “cartridge brass” - loss of ~ 3% in “depth”. Maintain the full angular coverage and the full Gaussian momentum resolution. The depth is slightly reduced (“tails”) and the calibration redundancy (LED + Laser + Source) is reduced. The longitudinal sampling frequency may be reduced. HF “tag jets” are not compromised.



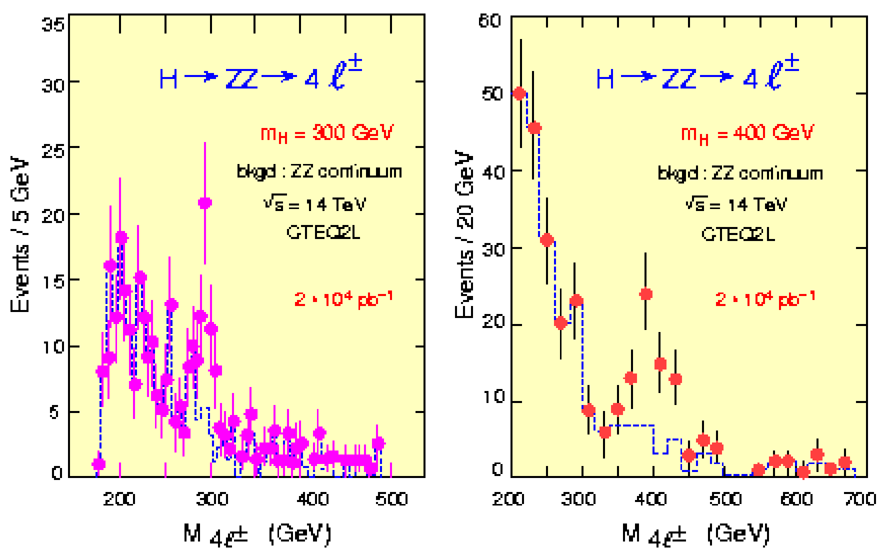
Rescoping and Physics

- **WBS 3. - TRIDAS: Maintain the L1 trigger unchanged (MF4). Reduce the bandwidth for DAQ from 100 --> 75 kHz. The “discovery level” trigger “cocktail” is unaffected. The efficiency for low Pt B physics is reduced, but the high mass Physics is untouched.**

$$H \rightarrow ZZ \rightarrow 4\ell^{\pm}$$

$E_t^e > 20, 15, 10, 10$ GeV; $|\eta^e| < 2.5$

$p_t^\mu > 20, 10, 5, 5$ GeV; $|\eta^\mu| < 2.4$



Rescoping and Physics

- **WBS 4. - ECAL: The tasks for thermal modeling and crystal lapping were dropped by the US and picked up elsewhere in CMS. There is no physics impact.**

- **WBS 5. - FPIX: The EDIA for the pixel readout chip parallel development is dropped. The “PSI ROC” used in the barrel will be adopted. There is no loss of physics.**

- **WBS 6. - CP: There is no change to the magnet. This was a basic decision to preserve full field and aperture - lever arm in CMS. The contracts for CP are awarded for ~ 1/2 the total estimated cost making redesign unacceptable.**

- **WBS 7. - PO: There is no major change in the PO, beyond a modest increase.**

Committee Concerns and Actions Taken

- **The US CMS deliverables have been rescoped in order to be in accordance with HEP experience on contingency levels.**

- **This exercise was initiated by US CMS but was iterated with CMS and that process resulted in a globally optimized CMS detector for Physics.**

- **The engineering effort in US CMS have been strengthened with the addition of a lead engineer for HCAL, CP, and EMU and an E.E. for HCAL.**

Summary and Conclusions

- Significant technical progress has been made in the last year. A TDR exists for 5 of the CMS subsystems.
- US CMS is moving from R&D (97) into PPP (98) prior to detector production (99).
- The Physics of CMS has been preserved in the resulting scope reduction of 17% of the base cost w.r.t. a new "bottoms up" cost estimate.